National Aeronautics and Space Administration

Commercial Sensor Survey Status Report

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1.0 Introduction and Task Objective

The NEPP FY07 Sensor Technology Commercial Sensor Survey task is geared toward benefiting future NASA space missions with low-cost, short-duty-cycle, visible imaging needs. Such applications could include imaging for educational outreach purposes or short surveys of spacecraft, planetary, or lunar surfaces. Under the task, inexpensive commercial grade sensors (e.g., CMOS-based "camera on a chip" systems) have been surveyed and selected for ionizing dose and displacement damage tolerance testing. Only inexpensive, commercial imagers with potential for use in low-duty-cycle space exploration applications have been considered; *the task does not address high-cost science grade imagers or hardened technologies.* The selected sensors had to meet selection criteria geared toward supporting small, low-mass cameras that produce good resolution color images. This document discusses the selection process.

2.0 Survey Guidelines for Candidate Sensors

The survey for candidate test sensors focused primarily on low-cost (from a few tens of dollars to a few hundred dollars per sensor), low-power, commercial CMOS sensor products, such as those used in cell phones, webcams, or consumer-grade digital still cameras. Charge coupled devices (CCDs) are typically at least an order of magnitude higher in cost than their CMOS counterparts, and they also require more complicated support circuitry to evaluate. Therefore, we did not put emphasis on CCDs in FY07. Cameras for outreach programs or low-cost surveys should be relatively inexpensive to both build and host on a spacecraft and, ideally, they should be small in size. Limitations on telemetry bandwidths, power, mass, and requirements on spacecraft real estate are key considerations that helped to guide the choice of which sensors to target.

Small bandwidths suggest that large arrays with as many as 14 Megapixels (Mpixel) may not be practical for the applications we are considering. In fact, many space missions have successfully used 0.5- to 2-Mpixel monochromatic CCD cameras with filter wheels to provide excellent images. However, filter wheels add expense and also significant mass, so the choice of color detectors with 1 to 5 Mpixel (which can provide similar color resolution) presents a reasonable compromise.

Optics are an additional camera cost driver, so it is important to keep them small when designing an inexpensive camera. Common small detector optical formats are 1/4, 1/3, 1/2.5, and 1/2 inch. For a fixed set of optics, decreasing the pixel size can increase resolution, but it also decreases the amount of signal charge that an individual pixel can collect, which reduces dynamic range. Note that the photosensitive active area of pixels, the portion of which is described as "fill factor," is further reduced in CMOS sensors due to the presence of circuitry within the individual pixels. This problem is mitigated in some sensor designs by the use of microlenses. Microlenses are small lenses that are placed directly on top of the pixels to focus light into the photosensitive region of the pixel.

Our trades led us to consider pixels widths between ~2 and 8 microns (μm), array sizes of ~1 to 6 Mpixel, color arrays, and 1/4- to 1/2-inch optical formats. Candidates also had to be available as packaged parts, not bare die.

The major criteria for selection were:

(1) Low cost.
(2) Sensor format, geared toward suitability for the applications mentioned above.
(3) **Relative ease of evaluation** (with the goal to minimize test development costs): A manufacturer-endorsed evaluation kit had to be available for the sensor line, and the kit was required to have the potential to easily adapt to the logistics of incremental dose testing on multiple samples. Our requirements also included the ability of the evaluation kit to produce RAW format images and provide direct control over a few select parameters, such as integration time.

3.0 Sensor Selection for 2007

The baseline approach to selecting sensors for FY07 testing was to gather information on available products from established companies in the commercial sensor industry and then make a down select based on the above criteria. This strategy was not entirely feasible, as we experienced general difficulty in acquiring product technical information from commercial CMOS companies and their distributors without making a commitment to buy and/or sign non-disclosure agreements (NDAs). For some sensor manufacturers, a non-disclosure agreement would have been required to receive even basic technical data sheets.

We adapted our strategy and procured limited quantities of promising sensors and evaluation kits while pursuing additional technical information in parallel. The low cost of the products we were investigating allowed us to gain technical information following actual procurement, with samples of the sensors and kits in-hand. This updated survey report discusses the selected 2007 test candidates and other sensors we investigated.

3.1 Micron

Micron produces several CMOS sensors with VGA (video graphics array: 640×480) to multi-Mpixel resolution. They are a major producer of CMOS sensors, having acquired Photobit's CMOS active pixel sensor technology in 2001. We selected the following Micron test candidates for NEPP:

3.1.1 MT9P031 (5 Mpixel, 1/2.5 inch, 2.2 μm) – selected for FY07

The MT9P031 is a 5-Mpixel, 1/2.5-inch optical format, CMOS sensor with a 2592(H)×1944(V) color pixel array that employs an RGB Bayer pattern color filter. The pixel size is 2.2μm×2.2μm. This product is marketed for applications which include high-resolution network cameras, wide field of view cameras, and hybrid video cameras with high resolution stills. Among its features are a 12-bit, on-chip analog-to-digital converter;

381 mW power consumption while imaging at full resolution and 14 frames-per-second; and low dark current and read noise [1].

3.1.2 MT9T031 (3.1 Mpixel, 1/2 inch, 3.2 µm) – *selected for FY07*

The MT9T031 is a 3.1-Mpixel, 1/2-inch CMOS sensor with a 2048(H)×1536(V) pixel array and RGB Bayer pattern color filter. The pixel size is 3.2µm×3.2µm. This sensor has a 10-bit, on-chip analog-to-digital converter; 228 mW power consumption while imaging at full resolution and 12 frames-per-second; and low dark current and read noise. This sensor is also marketed for wide field of view cameras, video cameras, and high resolution stills [2].

3.1.3 Micron Evaluation Kit

Evaluation of both of these sensors is supported by Micron's Demo2 Evaluation Hardware Kit and accompanying DevWare software. The kit allows characterization of all CMOS sensors within Micron's 3- and 5-Mpixel lines by use of interchangeable camera headboards that are customized for each sensor product. We have purchased both full evaluation cameras (see Fig. 1) and spare headboards for the MT9P031 and MT9T031. The headboards for each of our Micron candidates will be modified to include a test sample socket. This headboard modification will allow many sensor samples to be evaluated using the same headboard electronics. As purchased, each headboard comes with a permanently attached sensor sample for customer development use.

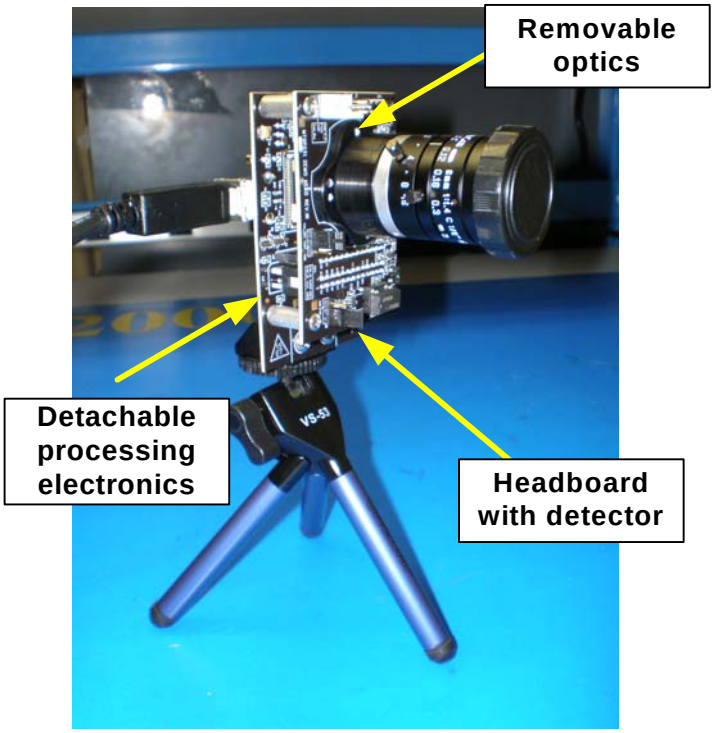

Fig. 1. Micron CMOS sensor evaluation camera.

3.2 OmniVision

OmniVision is another major manufacturer of low-cost CMOS detectors, but it requires an NDA before supplying product data sheets to potential customers. Based on publicly available product briefs, we identified promising 3- and 5-Mpixel RGB sensors with 2.2μm×2.2μm pixels and 1/4 to 1/2.5 optical formats. These sensors produce RAW output and have power consumption on the order of 120 mW [3],[4].

3.2.1 OV3630 (3.2 Mpixel, 1/3.2 inch, 2.2 μm) – *selected for FY07*

Following procurement of an evaluation kit for OmniVision's 5.17-Mpixel, 2.2μm×2.2μm pixel, 1/2.5-inch OV5620 sensor, we found that data would only be accessible to us in a 3-Mpixel format, implying that some form of pixel data binning was being performed. In order to allow full access of individual pixel data and to maintain an OmniVision candidate for 2007, we decided to select the OV3630, 3.2-Mpixel, 2.2μm×2.2μm pixel, 1/3.2-inch sensor for testing. This sensor has an on-chip, 10-bit ADC and operates in both video and snapshot mode. The design of the OV3630 evaluation kit allows test samples to be irradiated without removing them from the camera headboards. Test samples were procured as individual evaluation kits.

3.3 Cypress

Cypress recently procured FillFactory, a producer of CMOS sensor products for digital photography, machine vision, and space applications. Their space application CMOS sensors include the monochrome STAR and High Accuracy Sensor (HAS) lines; these products were outside of the price constraints of our survey, and considerable radiation characterization has already been performed (or is in process) by other investigators. We are considering detectors from Cypress's IBIS line as potential candidates in the future. For example, the 1280(H)×1024(V), 1.3-Mpixel IBIS5-B-1300 has a 2/3-inch optical format and 6.7μm×6.7 μm pixels [5]. The IBIS4-A-6600 is a 1-inch optical format sensor with a 2210(H)×3002(V), 6.6-Mpixel array and 3.5μm×3.5μm pixels [6]. Both detectors have 10-bit ADCs, and power consumption is on the order of 200 mW. Cypress supports evaluation kits for their sensors which give complete control over sensor operation. These sensor products range in price from $200 to $450 each, which is at the upper cost end of detectors under consideration. Because of the mid-range cost and larger size, these sensors were not selected in FY07, but they might be investigated in future years for NEPP.

3.4 Additional Surveyed CMOS Manufacturers

3.4.1 Kodak

Kodak is a leading manufacturer of CMOS sensor technology and has previously supported development kits which would have been very effective in evaluating some of the older Kodak products that meet our selection criteria. Unfortunately, during product inquiries with Kodak, we were told that they have recently shifted their focus to target the

automotive and cell phone industries and, as a result, they will not continue to offer CMOS sensors above VGA resolution at the present time.

3.4.2 Sony

Sony produces a line of CMOS sensors, which are used in some of their camera products. One of their more recent CMOS sensors is the 1/1.8-inch, 2.5μm×2.5μm pixel, 6.4-Mpixel, IMX017CQE [7]. While their CMOS sensors were not currently available for purchase as piece parts in the United States, sensors such as the IMX017CQE would be suitable candidates for testing if purchase in the United States were to become feasible in the future.

3.4.3 Dalsa

Dalsa is another leader in the digital imaging industry. Unfortunately, Dalsa does not market their Mpixel CMOS products as individual sensors. They are only available as integrated parts of Dalsa's camera products. Modification of these cameras for sensor radiation testing and evaluation was not practical within the scope of this task.

4.0 References

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